Infection, Incest, and Iniquity: Neural Correlates of Disgust and Morality

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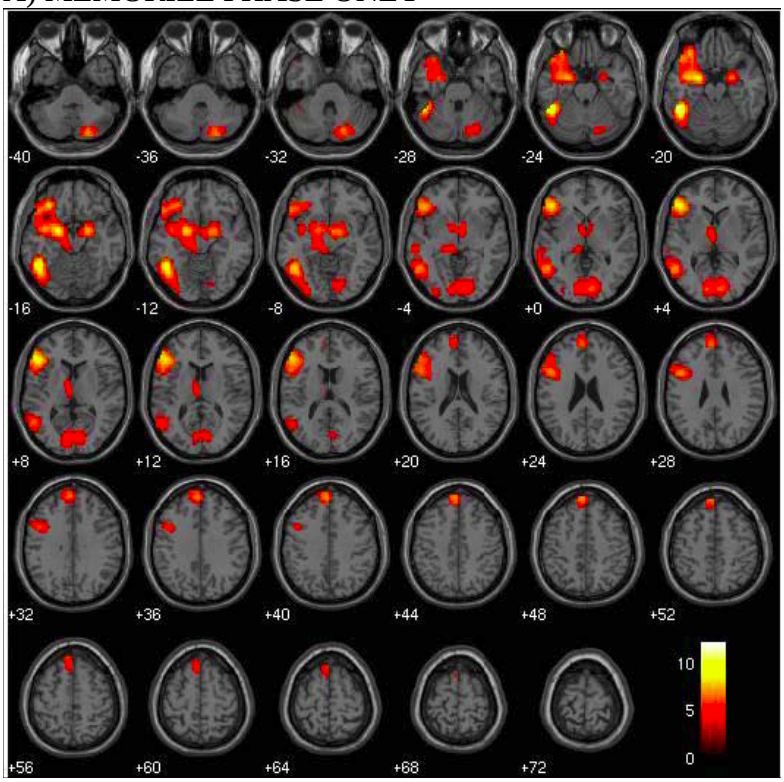
SUPPLEMENTARY MATERIAL

1. As stated in the last paragraph of the main text, the analyses reported in this study were all completed on the "memorize" and "recall" phases of the task put together as one block (similar to the primary analysis reported by Kiehl et al., 2001) because there was no strong a priori reason to analyze one phase over the other. An important question to ask is in the future, however, is do the neural correlates of the disgust conditions in the present study interact with the phase of the task, such that the neural correlates change from the "memorize" to the "recall" phases? Limited space prevents us from discussing this question in depth, but as summarized in Figure S1 below, the answer is yes. More details of this interaction will be reported in future publications.

Figure S1a. Interaction of disgust conditions and task phase: Pathogen > Neutral (FDR corrected p<.001), overlaid on SPM2 canonical T1 brain. (cluster minimum = 10 voxels, Neurological convention)

A) MEMORIZE PHASE ONLY



B) RECALL PHASE ONLY

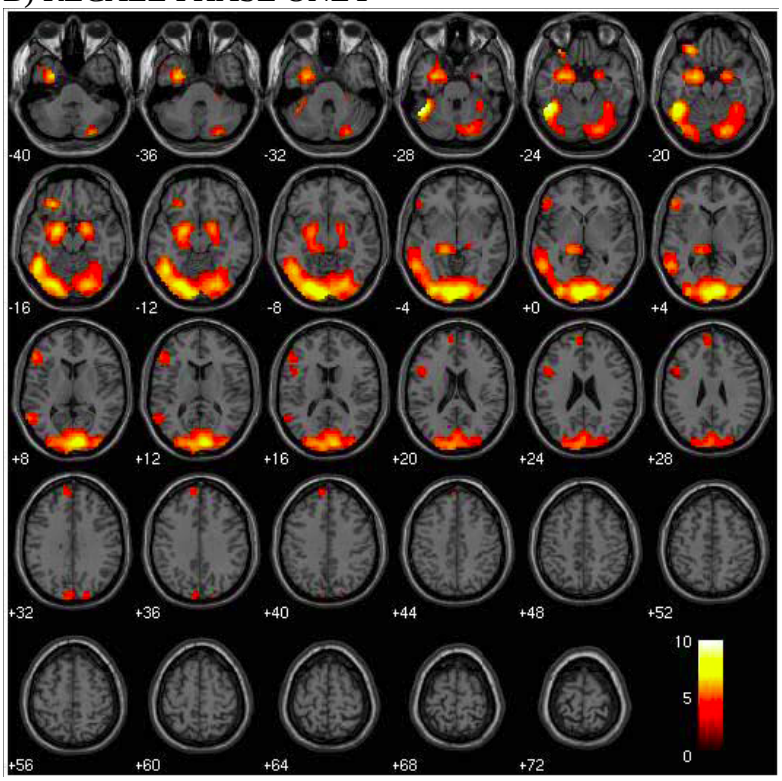
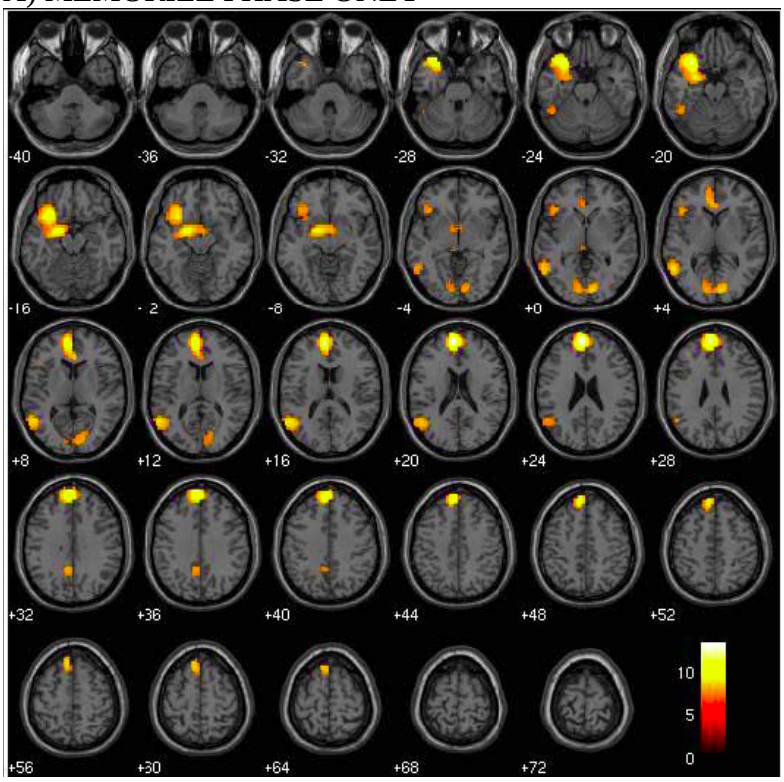


Figure S1b. Interaction of disgust conditions and task phase: Incest > Neutral (FDR corrected p<.0000001), overlaid on SPM2 canonical T1 brain. (cluster minimum = 10 voxels, Neurological convention)

A) MEMORIZE PHASE ONLY



B) RECALL PHASE ONLY

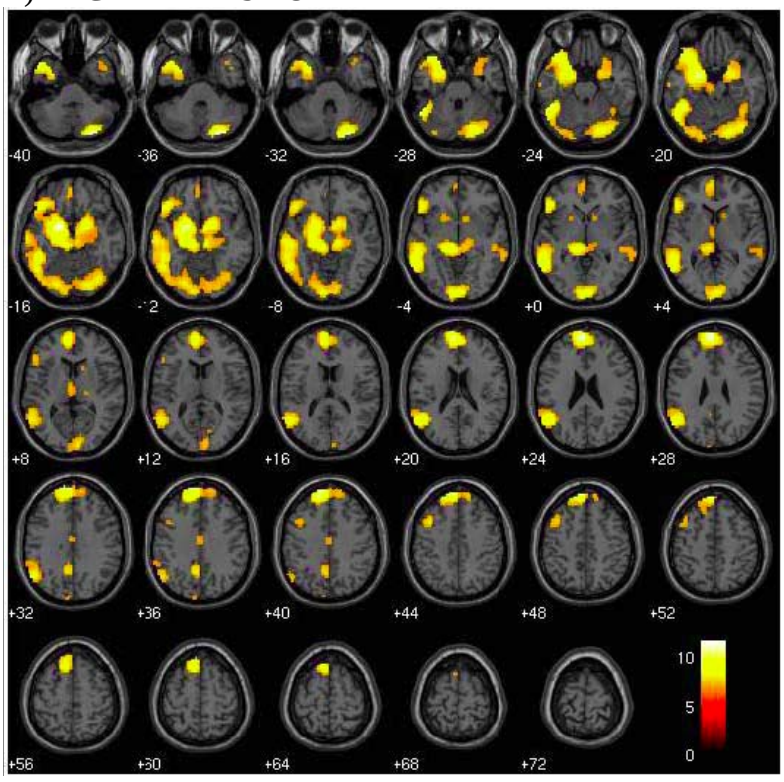
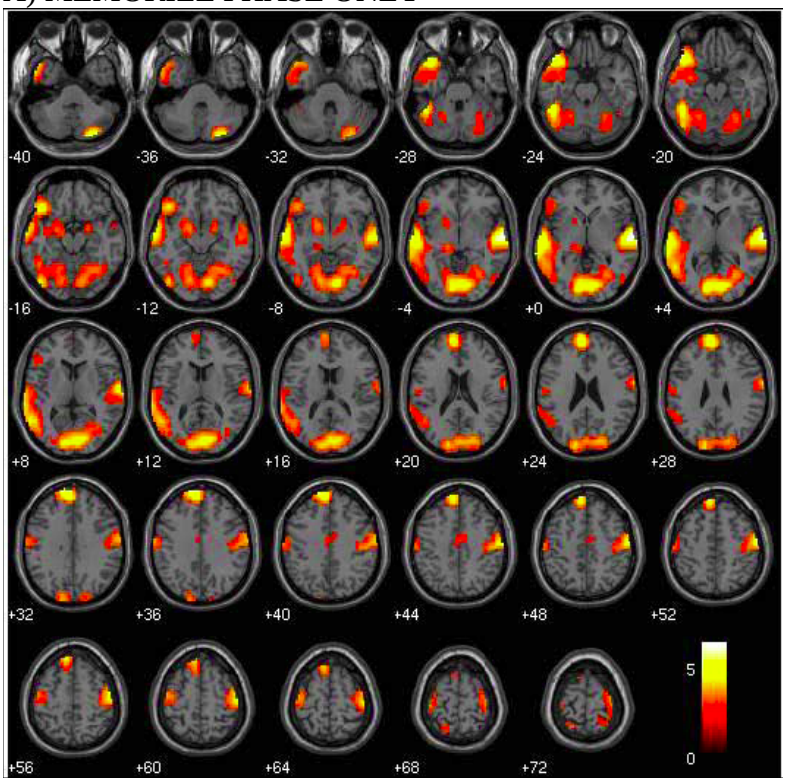
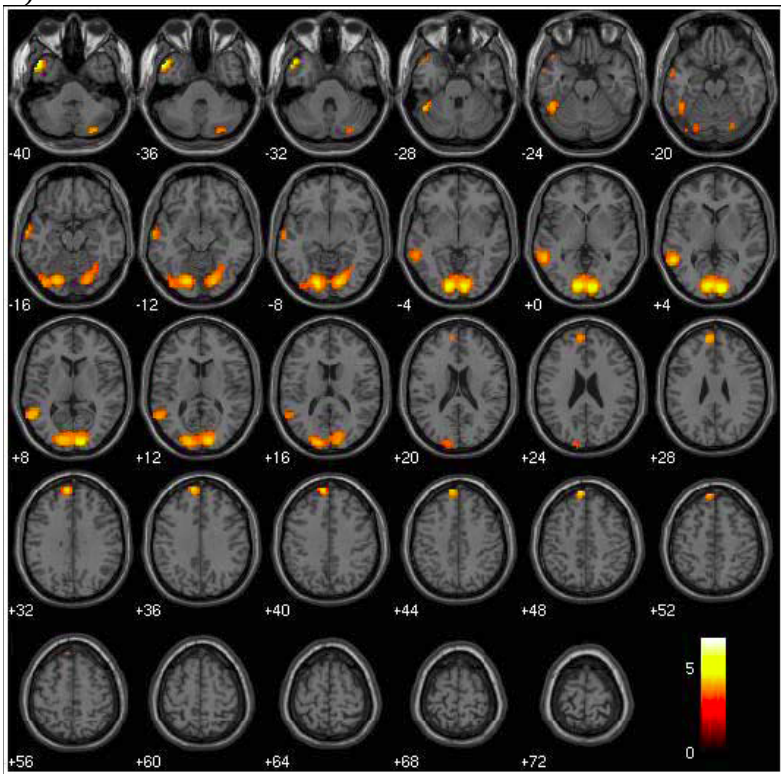


Figure S1c. Interaction of disgust conditions and task phase: Moral > Neutral (FDR corrected p<.05), overlaid on SPM2 canonical T1 brain. (cluster minimum = 10 voxels, Neurological convention)

A) MEMORIZE PHASE ONLY



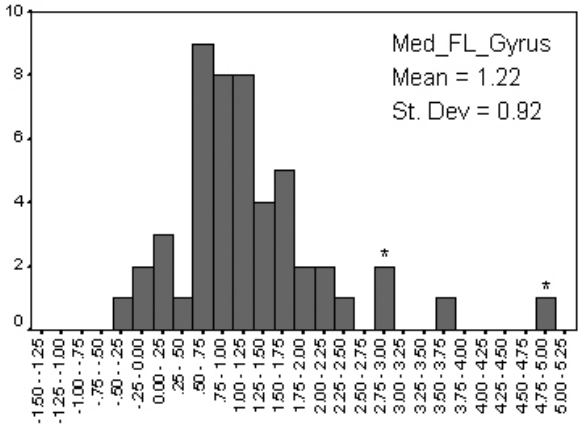
B) RECALL PHASE ONLY

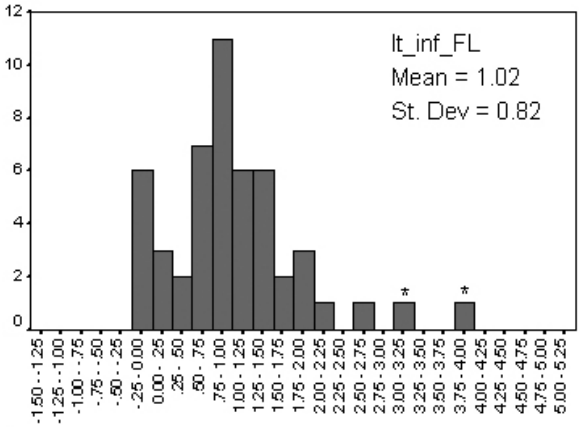


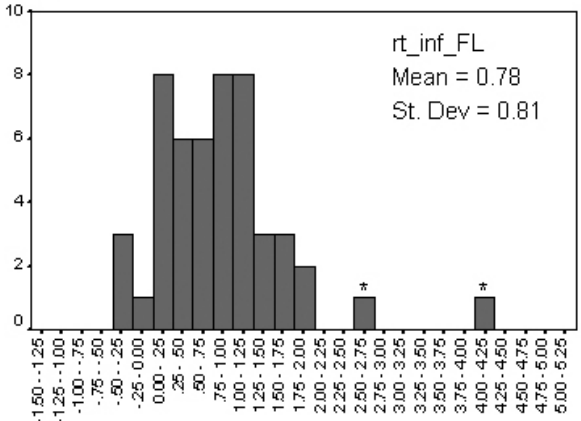
2. As stated in the *Incest > Moral* section of the main text, the Incest manipulation was very powerful in this study, so the results of the I>M contrast were highly statistically significant and included many brain regions. It may seem surprising that such dramatic differences can be observed between two types of moral stimuli that are rated to be equally moral wrong. To demonstrate the robustness of the results we report in our I>M contrast and to confirm that the reported results for the I > M contrast are not due to methodological error, we plotted histograms of each subject's parameter estimates for each anatomical region reported in Table 5 of the main text as taken from their derivative-boosted I>M contrast map (Calhoun et al., 2004). Each histogram shows the fifty individual subject parameter estimates at the indicated voxel and anatomical region reported in Table 5 of the main text (the coordinates of the voxel used for the rt_caudate, lt_brainstem, and rt_brainstem histograms was [9, 6, 9], [-9, -18, -18] and [9, -21, -15], respectively). From these histograms, it is clear that the data follow normal distributions and that many subjects have very strong responses to the Incest condition. This makes it unlikely that the dramatic effects we see at the group level are due to methodological complications like mechanical malfunctions in the scanner. It is also clear that there are two outliers in our subject population (according to their z scores,Tabachnik and Fidell, 1996). When we removed these two participants from the analysis (indicated by asterisks in the histograms), the group level t-scores actually improved slightly and the spatial expansiveness of the regions increased slightly as well. Nevertheless, we chose to report the analyses of all fifty participants in the main text.

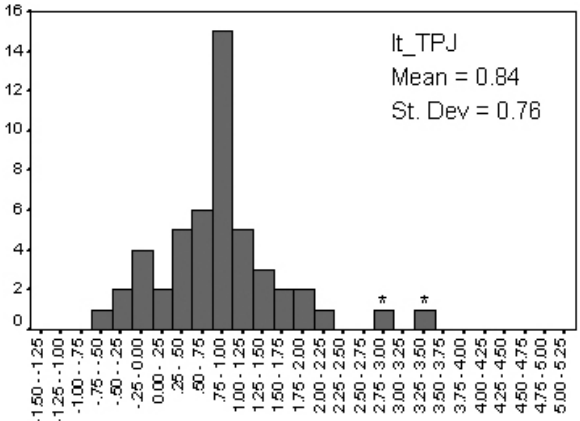
Table 5 from the main text. Regions more activated in Incest condition compared to the Moral condition. Brodmann's Area (BA), MNI coordinates, number of voxels (Z, letters indicate same cluster), and t-value (t) of each cluster > 10 voxels are reported.

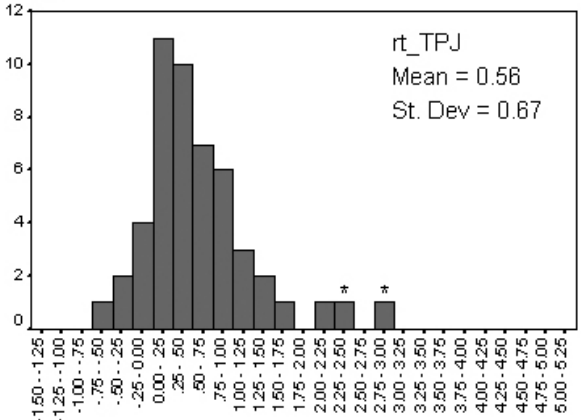
Incest > Moral (FDR corrected, p<.0001)						
		MNI Coordinates				
Brain Region	BA	x	y	z	Z	t
Frontal Lobes						
Med. FL Gyrus, Sup. FL Gyrus	10/9	-9	54	9	A - 4499	9.67
Bilat. Inf. FL. Gyrus	47	27	21	-21	A - 4499	7.28
(into insula on L side)	13	-27	21	-21	A - 4499	7.28
Temporal Lobes						
Bilat. Angular Gyrus (includes bilat. TPJ)	39	-51	-60	18	B - 820	6.82
(extends into Sup./Mid. Temp. Gyri)		57	-66	24	C - 73	5.13
	22	63	-57	15	C - 73	5.36
Lt. Supramarginal Gyrus	40	-57	-42	30	D - 11	4.89
Parietal Lobes						
Precuneus/Posterior Cingulate	7/31	-6	-54	36	E - 291	5.73
Occipital Lobes						
Lt Fusiform Gyrus	37	-45	-48	-18	F - 820	6.15
Limbic System/ Basal Ganglia						
Anterior Cingulate (Ventral)	32/24	0	36	3	A - 4499	9.43
Anterior Cingulate (Dorsal)	24	0	-15	36	G - 22	5.15
Lt. Amygdala					A - 4499	
Lt. Hippocampus					A - 4499	
Bilat. Caud./Globus Pallidus/ Putamen					A - 4499	
Bilat. Thalamus					A - 4499	

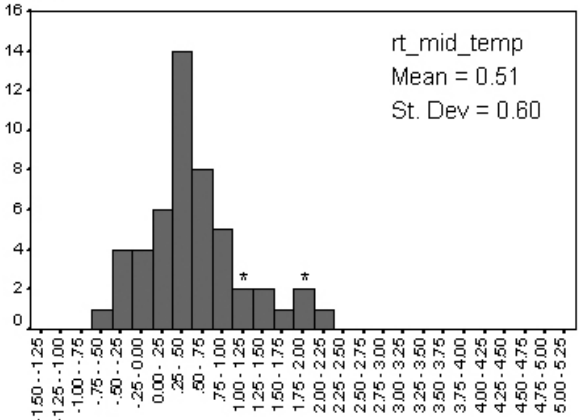

Med_FL_Gyrus
Mean = 1.22
St. Dev = 0.92

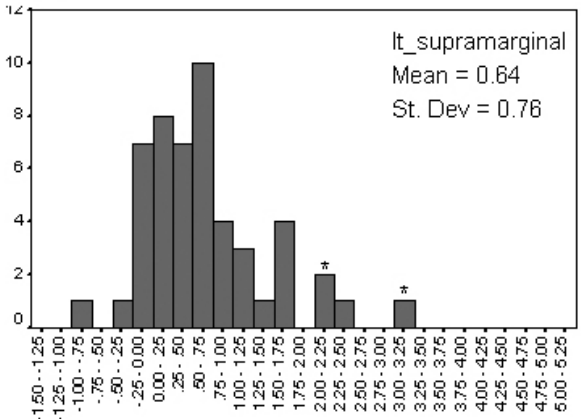

lt_inf_FL
Mean = 1.02
St. Dev = 0.82

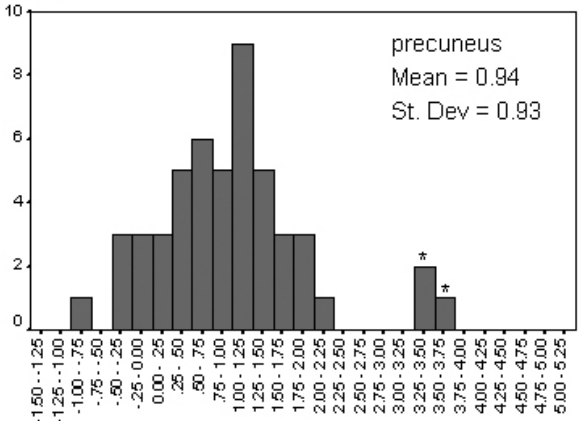

rt_inf_FL
Mean = 0.78
St. Dev = 0.81

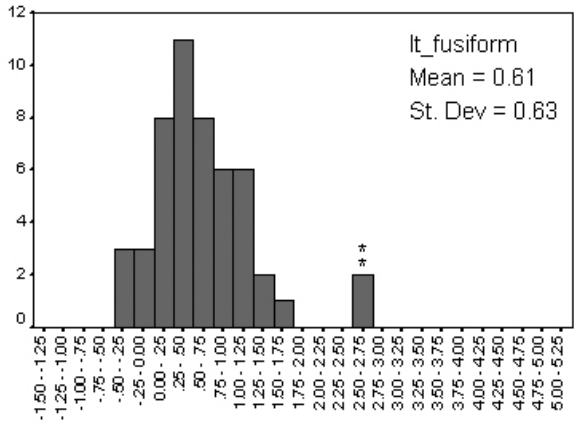

lt_TPJ
Mean = 0.84
St. Dev = 0.76

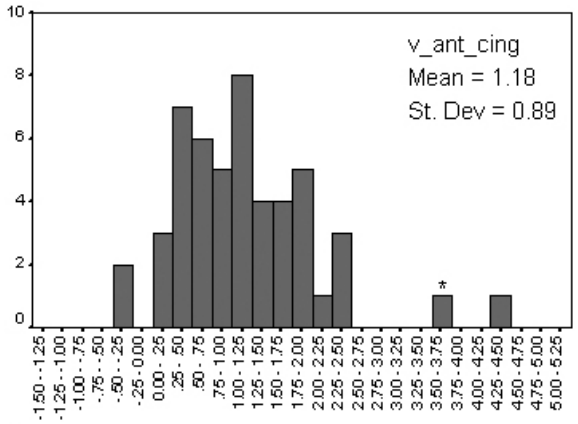

rt_TPJ
Mean = 0.56
St. Dev = 0.67

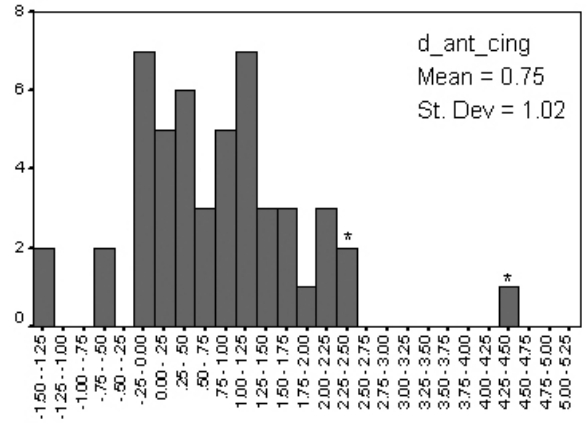

rt_mid_temp
Mean = 0.51
St. Dev = 0.60

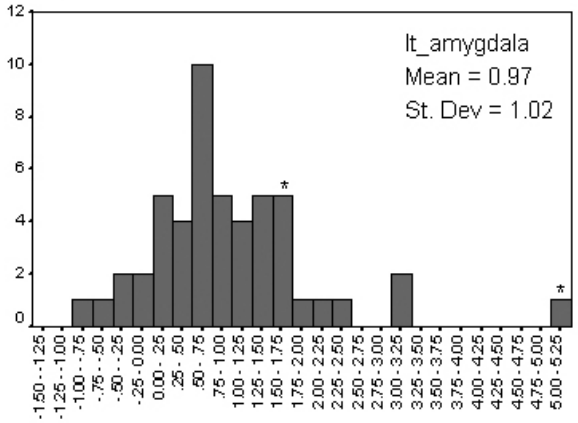

lt_supramarginal
Mean = 0.64
St. Dev = 0.76

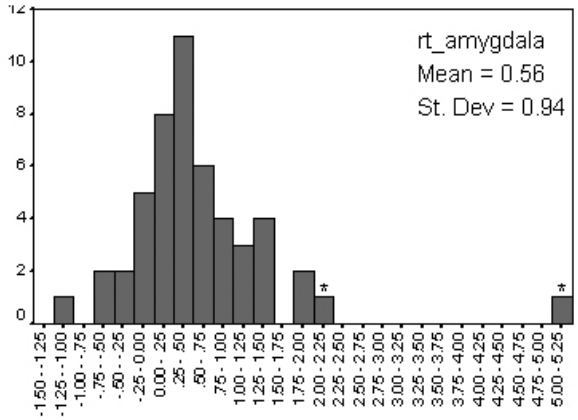

precuneus
Mean = 0.94
St. Dev = 0.93

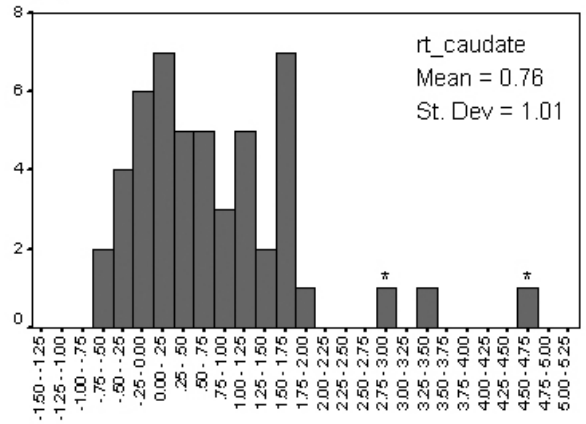

lt_fusiform
Mean = 0.61
St. Dev = 0.63

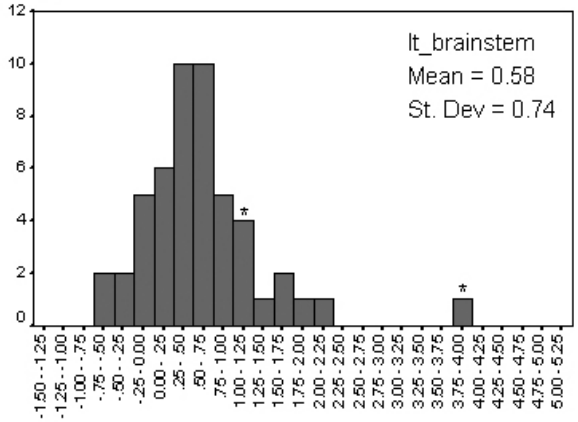

v_ant_cing
Mean = 1.18
St. Dev = 0.89

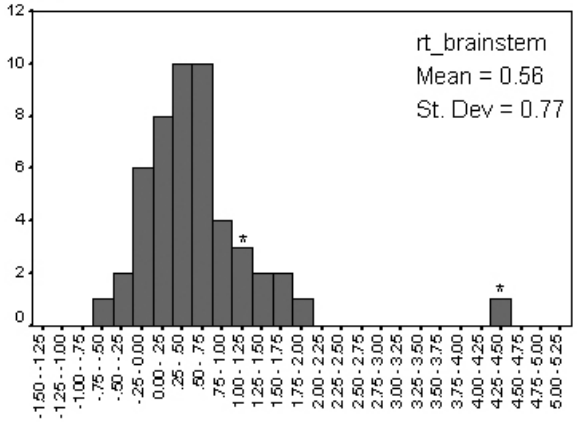

d_ant_cing
Mean = 0.75
St. Dev = 1.02


lt_amygdala
Mean = 0.97
St. Dev = 1.02


rt_amygdala
Mean = 0.56
St. Dev = 0.94

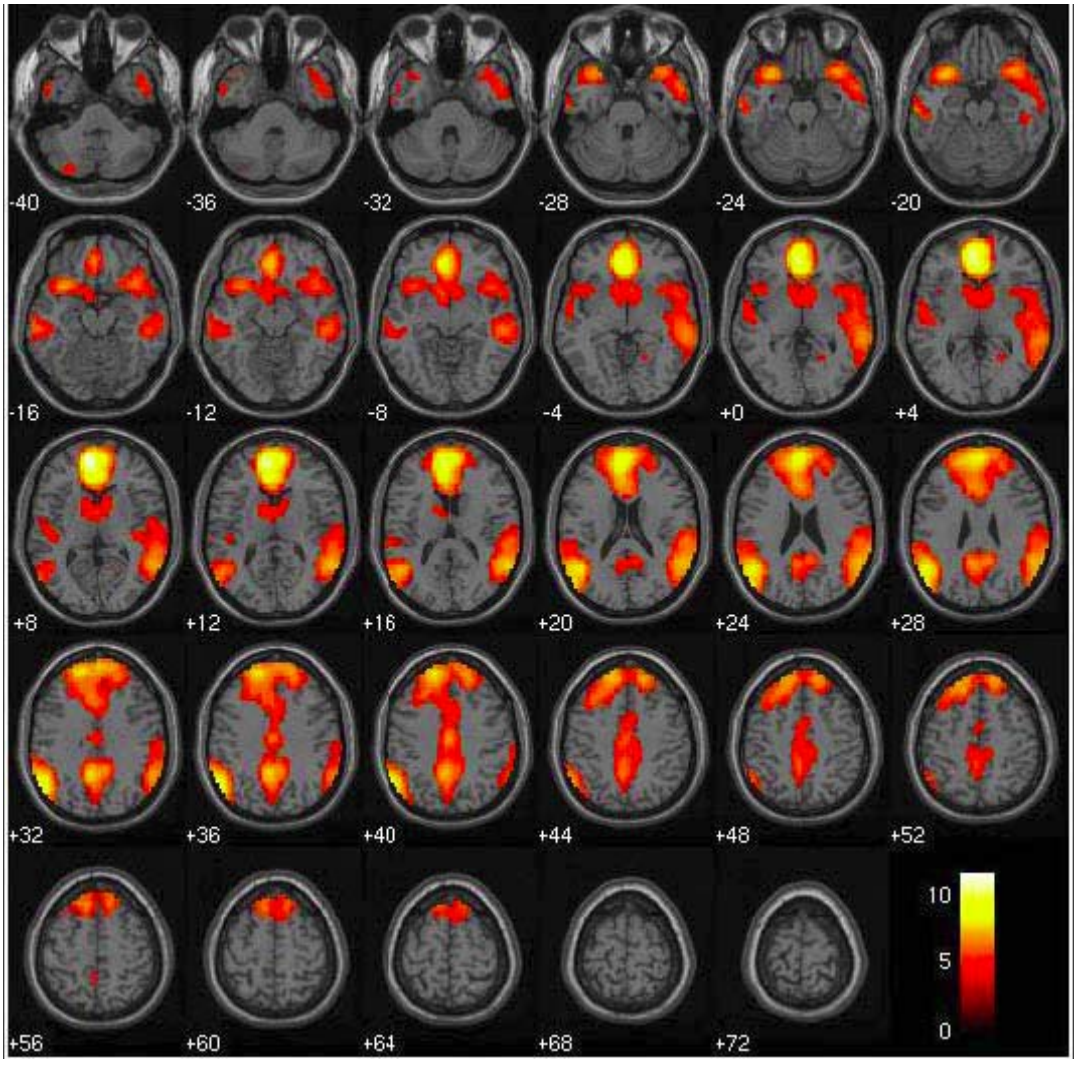

rt_caudate
Mean = 0.76
St. Dev = 1.01


lt_brainstem
Mean = 0.58
St. Dev = 0.74


rt_brainstem
Mean = 0.56
St. Dev = 0.77

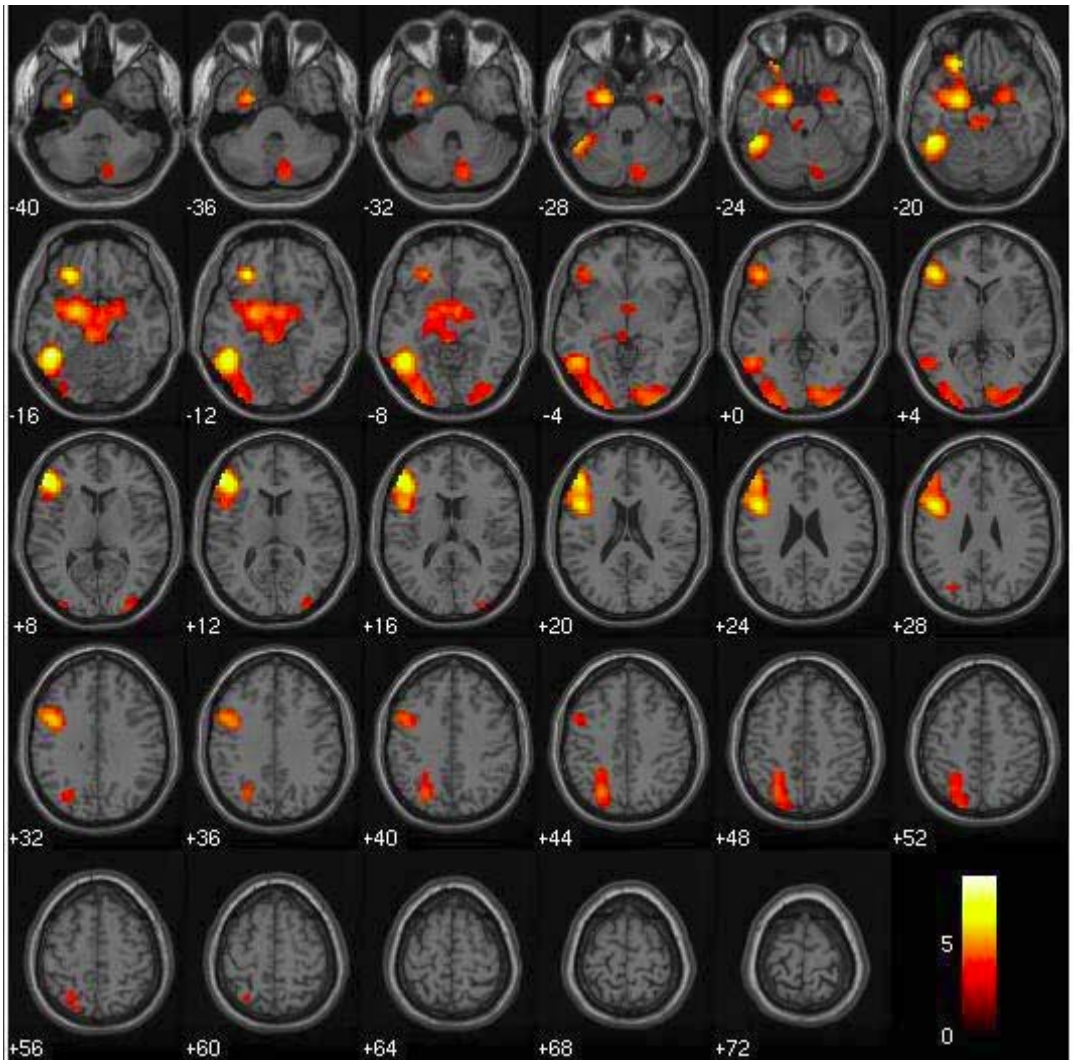
3. As described in the "*Socio-moral disgust: a unified phenomenon"* section of the main text, even though the Incest and Pathogen acts were rated as equally disgusting, the Incest > Pathogen contrast yielded a large network of brain areas very similar to those identified in the Socio-moral > Pathogen contrast (Figure S3). Additional significant voxels were identified in the lateral temporal poles (lt = -33, 18, -28; rt =36, 18, -27), the right inferior frontal gyrus extending into the anterior insula (39, 21, -21), bilateral middle temporal gyri (lt = -61, -27, -16; rt = 63, -36, 0), superior temporal gyri (lt = -54, -18, 6; rt = 63, -18, 3), and the right supramarginal gyrus (60, -54, 27) extending into inferior regions all around the temporo-parietal junction. Fewer significant voxels were found in the basal ganglia, and unlike the Socio-moral > Pathogen contrast, no voxels were found in the brainstem and left fusiform gyrus.

Figure S3: Incest > Pathogen overlaid on SPM2 canonical T1 brain. (FDR corrected p<.0001, cluster minimum = 10 voxels, Neurological convention).



4. As stated in the "*Socio-moral disgust: a unified phenomenon"* section of the main text, the Pathogen > Moral contrast yielded results very similar to the Pathogen > Sociomoral contrast with added significant activity in both amygdalae (lt amygdala = 24, -3, -24; rt amygdala = 23, -1, -21), brainstem (lt brainstem = -6, -29, -15; rt brainstem = 3, -27, -18), and ventromedial basal ganglia (lt = -6, 0, -9; rt = 6, -2, -6) (Figure S4). There was slightly less significant activity in the visual cortex compared to the results of the Pathogen > Sociomoral contrast.

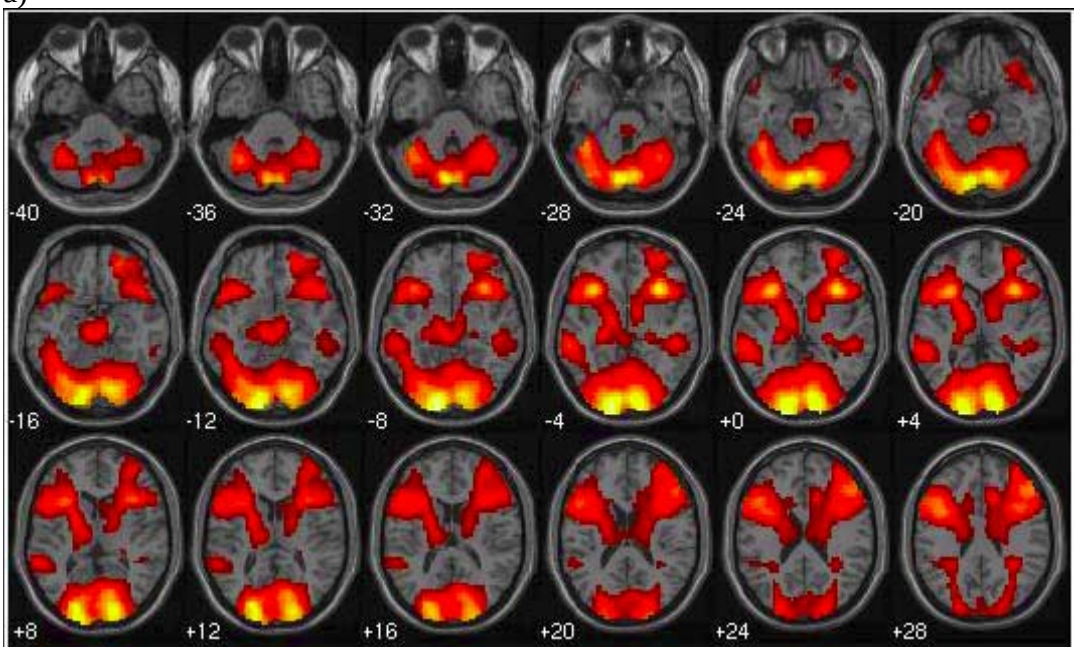
Figure S4: Pathogen > Moral overlaid on SPM2 canonical T1 brain. (FDR corrected p<.01, cluster minimum = 10 voxels, Neurological convention).



5. Many disgust researchers argue that the insula is the seat of disgust processing (Calder, 2003; Phillips et al., 1998). Although, as we stated in the text, many disgust studies have failed to find the insula to be more active in disgust conditions compared to control conditions (Phillips et al., 2004; Schafer et al., 2005; Stark et al., 2005; Stark et al., 2003) and visual inspection of published figures suggests some reported insula activity may be more accurately localized to other brain regions (most often the inferior frontal gyrus), we wanted to explore whether the lack of insula activity in the present study was due to a) an inherent presence of insular activity associated with neutral conditions or b) tonic insula activity in response to the provocative nature of the disgusting stimuli that carried over into neutral blocks. To address this, first we compared the Neutral condition to baseline to determine if the insula was active during processing of Neutral acts (Figure S5a). Indeed, it was, bilaterally. Were these results due to carry-over effects? It is doubtful. A contrast of just the first blocks of neutral stimuli, which were the first acts presented to subjects and therefore immune to carry-over effects, compared to baseline also revealed insular activity (Figure S5b). These exploratory analyses suggest that the lack of insular activity in our conjunction analyses was probably due to a presence of insular activity in neutral conditions.

Figure S5: a) Neutral > Baseline overlaid on SPM2 canonical T1 brain. Note bilateral insula activity indicating there were no technical difficulties preventing insula activity from being detected in other contrasts. b) First Neutral blocks (only) > Baseline overlaid on SPM2 canonical T1 brain. Insula is active even when no Pathogen or Socio-moral acts were previously presented. Thus carry-over effects are an unlikely explanation for the lack of insula activity in other contrasts. (FDR corrected p<.001, cluster minimum = 10 voxels, Neurological convention)

a)



b)